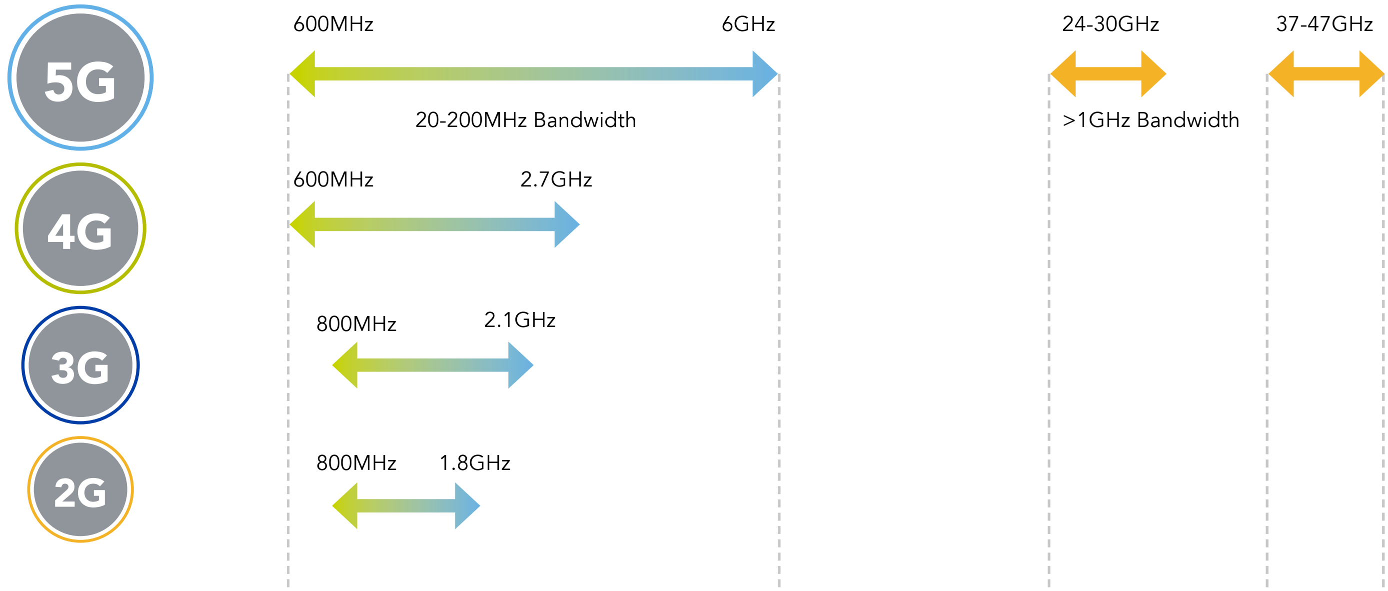
COMPLETING THE 5G PICTURE: *WHY mmWAVE IS A KEY PIECE OF THE PUZZLE*

While the transition to 5G will help the cellular infrastructure meet ongoing demand for higher capacity and performance, it's also much more than that. Taken as a whole, the 5G standards represent some of the most ambitious revisions ever released, and add groundbreaking new methods, technologies, and spectrum that, over the long haul, will help cellular reach its full potential. The new mmWave spectrum is key to that effort.

One of the things that sets 5G apart from previous generations of cellular is how much new spectrum it adds. In addition to supporting those parts of the spectrum where cellular currently operates (between 600 MHz and 2.7 GHz), 5G extends the present range up to 6 GHz and, more dramatically, adds spectrum in the frequency range above 24 GHz, a portion of the spectrum that has been, up to now, reserved for military, aerospace, and research applications.



New 5G Spectrum Gives Cellular the Room it Needs to Grow

These previously unavailable bands above 24 GHz, commonly referred to as millimeter wave (mmWave) due to their very short wavelengths, create a solid foundation for future growth. Many of the most impressive cellular use cases people are talking about – autonomous vehicles, self-guided robots and drones, immersive AR/VR everywhere – will eventually call this part of the spectrum home. That's because mmWave delivers the ultra-high data rates and near-zero latency required to run advanced, mission-critical applications.

A LONG TIME COMING

The mmWave spectrum has been used for radar and satellite communication for several decades, but opening it up to cellular is something very, very new. The center frequencies around 26, 28, and 34 GHz are particularly compelling, because they offer hundreds of megahertz of wireless transmission bandwidth. Those of us in the cellular industry have been eyeing these areas for some time, but up until only very recently, working with cellular at such high frequencies has posed too many technical challenges.

We faced two obstacles in particular. First, signals that use very short wavelengths and have much shorter transmission lengths than signals under 6 GHz. Also, mmWave signals have greater difficulty propagating through solid objects, such as building materials and trees. The hand holding a smartphone can cause interference, and even high levels of humidity in the air can hinder transmission. For a long time, these two main challenges – high propagation losses and poor performance in non-line-of-sight (NLOS) situations, meant we could not consider mmWave for cellular.

But technology has a way of evolving to meet the need. Recent advances in RF silicon, along with deeper understanding of channel characteristics and signal propagation, have made mmWave a viable option for cellular. Seeing the promise of using this new spectrum for future growth, the 3GPP quickly adopted it as a part of the new 5G standards.

ALREADY BEING DEPLOYED

Everything about mmWave cellular is still very new, but the infrastructure is starting to grow. There is strong support for mmWave in the United States and Asia Pacific in particular, and a number of cellular networks that use mmWave spectrum have either been deployed or are nearing completion. For example, mmWave will be part of the wireless enablement for major upcoming sports events in China, and in the US, a number of cities now offer mmWave service as part of Fixed Wireless Access (FWA) networks for home and business use.

We expect mmWave to play an important role in the infrastructure, working behind the scenes as part of macro cell backhaul and fiber extension, and as part of IoT expansions and Industry 4.0. New mmWave networks will also meet the growing demand for high-speed data in densely populated areas, such as city centers, and in public spaces where data congestion is often a problem, such as airports, sporting arenas, concert venues, and even large-scale shopping malls.

One such example is the Tampa International Airport in Florida, which recently deployed a mmWave service that lets all three major US wireless carriers offer 5G mobile network service throughout the facility.

The mmWave service has download speeds of up to 2 gigabits per second, which means passengers preparing for flights can download a full-length feature film, with a run time of around three and a half hours, in just seconds. The mmWave service even gives a boost to the 4G LTE experience, with more robust coverage on 4G LTE and download speeds of up to 300 Mbps.

5G is designed to co-exist with the latest versions of Wi-Fi, including Wi-Fi 6/6E, and mmWave is part of that. As users move between indoor and outdoor locations, they are likely to use a mix of Sub-6 GHz and mmWave 5G technology along with Wi-Fi. We also expect mmWave to be an important part of the trend toward Multi-access Edge Computing (MEC), which extends cloud-computing resources to support edge deployments and enables convenient, consistent service access at the edge, whether the service request is coming from 4G LTE, 5G, or Wi-Fi.

BEAMFORMING IS KEY

Because mmWave signals are different from those found below 6 GHz, the mmWave infrastructure needs to be different, too. A typical mmWave setup uses a dense network of small cells, each with a range of between 100 and 150 meters for mobile use cases. To ensure good coverage and reliable wireless links, the cells use phased array antennas with beamforming techniques as part of transmission and reception.

Beamforming is essential to mmWave operation. It's a technique that improves radio communication by focusing the wireless signal. Rather than let the transmitted signal spread out in all directions, as with a broadcast antenna, a beamforming antenna varies the amplitude and phase of the transmitted signal per antenna element to form a narrow beam that can be pointed in a desired direction.

Beamforming boosts the transmitted signal and minimizes noise and interference at the receiving end. That means the connection is more direct and more reliable. Beamforming also supports spatial multiplexing, which lets you use frequencies more than once in the same radio system when pointing different beams in different directions. That increases capacity without having to increase the allocated bandwidth. Also, because beamforming prevents the radio from broadcasting where signals are not needed, there is less interference for devices trying to pick up other signals. (That's part of the reason why the Tampa airport's mmWave deployment has the side effect of improving 4G LTE operation, too.)

First used in World War II to make sonar systems more effective, beamforming is now an essential part of both Wi-Fi and cellular operation. To support mmWave operation, new 5G beamforming algorithms use several techniques, including switching, steering, and tracking, to identify reflected energy in the signal path and redirect signal energy to alternative paths. The result is extended range, and the ability to use mmWave more effectively when line-of-sight (LOS) transmission is not possible.

THE ROLE OF MASSIVE MIMO

Beamforming is designed to work with radios that use MIMO (Multiple-In, Multiple-Out), a method that increases capacity by using more than one antenna to transmit and receive each packet. Signals operating at higher frequencies use more antennas. In a radio operating below 6 GHz, for example, the MIMO antenna array might use as many as eight antenna elements. But with mmWave, the number is more likely to be 64 or 256 (or even 1024). However, it's important to note that a higher number of antenna element also has drawbacks, with beams becoming narrower which makes it more challenging to track the user.

The antenna arrays used with mmWave are referred to as "massive MIMO" (mMIMO), but the physical units themselves are not big. The short wavelengths of mmWave signals are a benefit here, since the antennas they use are small, too. With recent advances in silicon manufacturing, the mMIMO arrays used for mmWave are now compact enough to fit in the tight spaces of smartphones, IoT devices, and roof-mounted "shark fin" antenna units on passenger vehicles.

PROCESS TECHNOLOGY MAKES IT POSSIBLE

High-frequency cellular is still very new for everyone involved, and the requirements for mmWave operation have led to novel approaches in design and manufacturing. One of the key challenges is on making mmWave radios more power-efficient. This has the obvious and important benefit of a lower system power consumption and also makes the antenna structure easier to keep cool. Thus for mmWave beamformers, NXP's main focus is on delivering the most energy-efficient solutions to the market.

At NXP, we have found that our QUBiC Silicon Germanium (SiGe) process technology hits the sweet spot for beamforming ICs, bringing an excellent balance of output power, linearity, efficiency and cost.

Thanks to our deep RF design and system expertise and close co-development, we have produced stable RF performance at frequencies across all major 5G mmWave bands. We are also in a unique position to tailor performance for specific applications in our fabs through close collaboration between the process technology and product design teams.

We currently offer 4-channel beamforming ICs for 26 GHz and 28 GHz. These low-loss, high-bandwidth circuits are compact solutions for mmWave applications and deliver exceptional performance for macro use cases up to and above 60 dBm EIRP. We employ cutting edge package technologies for our RF front-end components to deliver the full functionality in a compact footprint that fits within the antenna grid. The overall design also demonstrates superior thermal handling and lifetime reliability in a very demanding application.

NXP's innovative roadmap includes future developments to cater to all major global 5G bands with a full IF-to-antenna chipset offering for high and medium power outdoor RU systems.

MMWAVE REMAINS CUTTING EDGE

This is just the beginning of mmWave for cellular, and we expect the technology to keep evolving and improving over time. We are innovating our technology and designs to make it easier for our customers to make mmWave a part of their 5G cellular picture.

We have already succeeded in increasing throughput and extending range, and offer innovative infrastructure solutions that can be optimized and tailored for mmWave operation. We are the only company delivering RF and transceiver solutions across the complete range of 5G network deployments from sub-6GHz to mmWave, and we've established hardware and software partnerships with key multiple-system operators (MSOs) and Original Design Manufacturers (ODMs) to quickly deliver systems for 5G hyper-connectivity to the market.

To learn more about mmWave for cellular and how we are making it a reality, visit **www.nxp.com/5G**

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